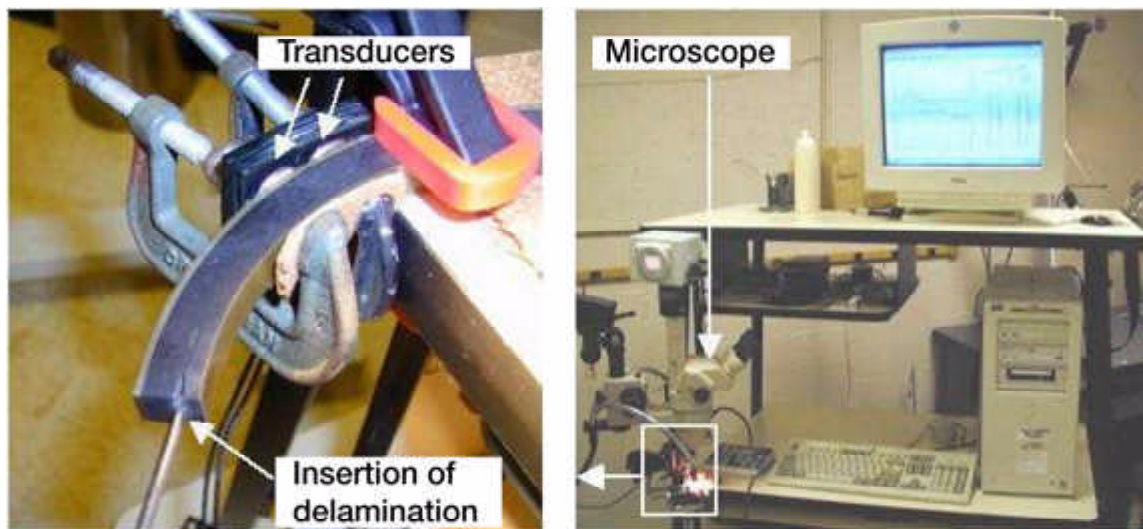


Delaminations Investigated With Ultrasonic Spectroscopy

A previous study suggested that the ultrasonic spectroscopy technique identified possible disbonds or delaminations in polymer matrix composite (PMC) rings sectioned from flywheel rotors (ref. 1). These results went unsubstantiated by other nondestructive evaluation (NDE) methods. To explain the results, PMC rings were further investigated with ultrasonic spectroscopy (ref. 2). The ultrasonic spectroscopy system utilizes a continuous-swept sine waveform as the input. After the swept sine wave traverses the material, the captured waveform is subjected to two fast Fourier transforms. The second fast Fourier transform along with equalization of the frequency spectrum, allows for evaluation of the fundamental resonant frequency. The full-thickness resonance, the resonance corresponding to the location of the intentional disbond, and the frequency spectrum were examined in an effort to characterize the sensitivity of the NDE method to various delamination conditions.



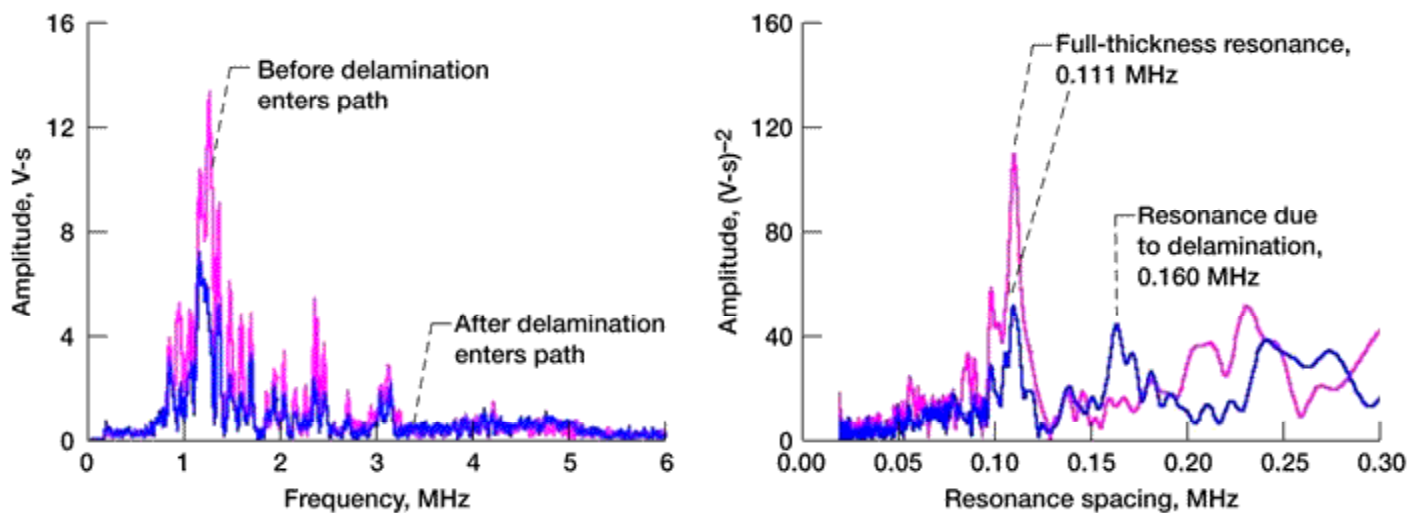
Experimental setup. Left: Transducers clamped to the outer face of a composite ring section while inserting a delamination. Right: Optical microscope and ultrasonic spectroscopy system utilized to collect data in 10 stages.

Long description of figure 1 Two photographs illustrating the experimental setup. Left: 90-degree section of a polymer composite ring with locations 3, 4, and 5 labeled. A screwdriver is inserted near location 5 to create a delamination. The ultrasonic transducers are on location 3. Right: Computer system in relation to the microscope, ring section, and transducers.

Ultrasonic spectroscopy responses were acquired as a delamination was initiated into a PMC ring section as shown in the photographs. A full circular ring was cut into four 90° sections. A groove was machined into the ring section near location 5. Next, a delamination was introduced by wedging a screwdriver into the groove. Transducers were clamped to the outer face of the composite ring section at location 3 while the

delamination was initiated and propagated through the section, as illustrated in the photographs. C-clamps were used to hold the transducers in place and keep coupling conditions constant. The clamps were not overly compressive to allow the delamination to propagate through location 3. Ten stages of ultrasonic and optical data were collected with the screwdriver holding the delamination open. The first stage was prior to initiating a delamination. Successive readings were collected as the delamination propagated toward, then through, location 3, where the transducers were located. The final stage, stage 10, was defined as a full delamination through the ultrasonic path of the transducers at location 3. The optical measurements of the apparent delamination openings were taken from the outside surface of the composite ring.

Only the full-thickness resonance was produced in a defect-free composite ring prior to initiating a delamination. Progression of a delamination into a monitored region of a composite ring section was detected as a change in the resonant frequencies. When a delamination with an apparent opening near 0.05 mm (0.002 in.) entered the ultrasonic path, it was detected as the appearance of a new resonance corresponding to the location of that delamination. The graphs show the ultrasonic spectroscopy response before and after the delamination enters the path of the transducers. A delamination with an apparent opening of approximately 0.07 mm (0.003 in.) through the whole ultrasonic path of the transducers resulted in a single resonance corresponding to its location without the presence of the full-thickness resonance. On the basis of these results, ultrasonic spectroscopy is a viable NDE tool in detecting and monitoring delaminations in composite rings to be used in flywheel rotors. These results can be extended to detecting delaminations in PMC materials.



The spectrum (left) and the spectrum resonance spacing (right) immediately before and after the delamination enters the transducer path exhibiting a reduction in amplitude in the spectrum and the appearance of a resonance due to the delamination in the spectrum resonance spacing. The 0.05-mm-thick delamination was through less than a quarter of the ultrasonic wave path.

Long description of figure 2 Two-part figure showing the ultrasonic spectroscopy response before and after the delamination enters the ultrasonic path of the transducers.

Left: Spectrum shown with a decrease in amplitude after the delamination enters the path.
Right: Spectrum resonance spacing shown with only the full-thickness resonance appearing before the delamination enters the path. When the delamination enters the ultrasonic path of the transducers, a resonance corresponding to the location of the delamination appears. In addition, the amplitude of the full thickness resonance reduces by half.

References

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